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TWENTIETH ANNUAL PROGRESS REPORT OF
THE PENNSYLVANIA STATE UNIVERSITY
BREAZEALE NUCLEAR REACTOR

July 1, 1974 to June 30, 1975

Submitted to
United States
Energy Research and Development Administration
and
The Pennsylvania State University

by

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MASTER

June 1975

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I. INTRODUCTION AND SUMMARY

The 20th Annual Progress Report of The Pennsylvania State University Breazeale Nuclear Reactor (PSBR) is prepared and submitted in accordance with the requirements of Contract No. AT(30-1)-3409 with the United States Energy Research and Development Administration. This report also provides a summary of the past year's operation for the University Administration.

Administrative responsibility for the Nuclear Reactor Facility rests with the Department of Nuclear Engineering in the College of Engineering. It operates, primarily, as a facility of the University that is available to the several colleges for their education and research programs. In addition, the Facility is made available to Commonwealth industries to provide irradiation services that are essential in solving their engineering research and development problems.

During this past year changes have occurred which are beginning to have a significant effect on the operation of the facility. The increase in the enrollment of associate and B.S. degree students are now requiring more laboratory facilities and staff time to conduct experiments and future schedules must plan for an increasing number of students. Utilization of the space in the accelerator building nearby is being increased and the nuclear engineering laboratories are expanding to handle the larger groups of students. At the same time, the general funds budget to maintain the equipment has been decreased, which emphasizes dependency upon contract funds.

Reactor usage continued at about the same pace as last year except that the energy produced, 710.4, MWH is about 30% less than

last year. However, the number of hours involved in approaching critical and operating at power was slightly greater this year. This is as expected since the reactor has recently been utilized more for training and instruction and such operation takes place at low power and requires more approaches to critical.

The impact of greater public interest in nuclear energy and the increased need for educating all facets of the public, including high school teachers and power plant operator trainees, in nuclear energy is reflected in the education and training activities at the PSBR. Approximately 2,700 visitors, including the Lt. Governor of Pennsylvania, toured the facility this year compared to 2,300 last year. A Nuclear Concepts summer institute for high school teachers was offered, and 32 separate high school nuclear science groups performed experiments at the facility. Experiments were conducted in the Co-60 facility for courses in Horticulture, Entomology, and Plant Sciences. Nuclear Medical Technology students, Alpha Fire Company personnel and state police made use of the facilities and staff in their programs, and the training of ambulance drivers and Ritenour Health Center personnel included instruction and demonstrations at the PSBR. This latter group took part in a drill which simulated rescuing a contaminated-injured person. Lectures and demonstrations were presented at the facility to local civic groups interested in nuclear energy.

The Radionuclear Application Laboratory has experienced a year of changes in programs and support personnel. Both the forensic effort and biomedical programs were completed this year and proposals

to continue these efforts have been submitted to the appropriate authorities. The other research programs involved in the development of radiation monitors and the use of nonradioactive but neutron activatable tracers in hydrological problems continue to receive support. A new project was begun this year by Dr. Keith and Dr. Rose of Geochemistry to develop detection techniques for trace amounts of uranium in both stream sediments and waters to identify upstream uranium deposits. Mr. Dale Raupach, Reactor Supervisor, was assigned part time to this laboratory to provide assistance to University personnel utilizing this facility.

A brief summary of other major happenings and accomplishments during this past year is as follows:

A new rapid pneumatic sample transit system for transferring irradiated samples from the reactor core to the detector system in less than one second is being installed.

Dr. S. H. Levine presented a 3 week work shop, on fuel management of TRIGA reactors, for the Mexican AEC at their laboratory near Mexico City.

A successful two-day workshop was organized by Dale Raupach to instruct research personnel in the use of non-radioactive but neutron activatable tracers as a research tool.

Two industrial training programs, one for the Metropolitan Edison Company and another for the Cincinnati Gas and Electric Company, were successfully completed this year.

Members of the facility staff continue to assume more responsibility in teaching and laboratory assignments.

The University Reactor Safeguards Committee met 4 times during the past year to consult with the staff on new or revised irradiation experiments, review operation records, and consult on special operational problems.

The next section provides a list of personnel who are associated with the operation of the reactor. Section III describes the PSBR Administrative organization and lists staff changes that have occurred this past year. Section IV provides pertinent information, including statistical data, on the PSBR's operation. Section V describes in some detail the various educational and training programs conducted at the PSBR and identifies staff participation. The activities and accomplishments of the Radionuclear Applications Laboratory is presented in Section VI. However, more detail on these and other research projects are presented in Section VII.

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II. PERSONNEL

Faculty and Staff

**T. L. Flinchbaugh	-Reactor Operation/Education Specialist
**G. C. Geisler	-Research Associate
**R. C. Houtz	-Reactor Supervisor
W. A. Jester	-Associate Professor
**S. H. Levine	-Professor
J. R. McKee	-Administrative Aide
**I. B. McMaster	-Research Assistant
**J. H. O'Brien	-Reactor Supervisor
**J. L. Penkala	-Research Assistant
K. K. Pillay	-Research Associate
K. N. Prasad	-Research Assistant (resigned October 1, 1974)
**D. C. Raupach	-Reactor Supervisor
G. E. Robinson	-Associate Professor
*K. E. Rudy	-Engineering Aide-Mechanical Service Supervisor
**R. E. Totenbier	-Research Assistant
*D. S. Vonada	-Electronics Designer

Technical Service Staff

W. A. Davy	-Custodian-Driver
*R. L. Fisher (part-time)	-Reactor Operator
J. P. Gauthier	-Custodian-Technician
L. W. Gardner (part-time)	-Reactor Operator
*R. E. Jones (part-time)	-Reactor Operator
R. O. Lowrey	-Machinist
*J. W. Martin (part-time)	-Reactor Operator
E. L. Resnick (part-time)	-Reactor Operator

Clerical

M. D. Beward	-Secretary
K. M. Loughrey	-Secretary and Receptionist

Graduate Assistants and AEC Trainees

*R. H. Arnold	-ERDA Trainee
*J. R. Bailey	-ERDA Trainee
**M. J. Cenko	-Graduate Assistant
J. G. Cocco	-ERDA Trainee
H. E. Collins	-Graduate Assistant
T. J. Donlan	-Graduate Assistant
D. C. Driscoll	-Graduate Assistant
C. A. Gresko	-ERDA Trainee

*G. W. Houston	-Graduate Trainee
R. H. Klinetob	-Graduate Assistant
R. L. Kuis	-Graduate Assistant
B. W. Lee	-Graduate Assistant
S. M. Mirsky	-Graduate Assistant
P. G. Newcomb	-Graduate Assistant
P. J. Rensen	-Graduate Assistant
P. J. Rose	-Graduate Assistant
W. G. Runte, Jr.	-Graduate Assistant
*J. D. Seebald	-Graduate Trainee
F. M. Sider	-Graduate Assistant
R. G. Sider	-Graduate Assistant
E. K. Stover	-Graduate Assistant
D. G. Tilley	-Graduate Assistant
E. G. Tourigny	-Graduate Assistant
F. A. Wolfe	-ERDA Trainee

Health Physics

R. W. Granlund	-University Health Physicist
J. K. Schmotzer	-Health Physics Assistant
M. J. Slobodien	-Associate Health Physicist

Reactor Safeguards Committee

Dr. A. H. Foderaro, Professor, Nuclear Engineering (Past Member)

Mr. G. C. Geisler, Research Associate and Assistant Director,
Breazeale Nuclear Reactor

Mr. R. W. Granlund, Health Physicist (Past Chairman)

Dr. A. M. Jacobs, Professor, Nuclear Engineering

Dr. E. S. Kenney, Professor, Nuclear Engineering (Past Member)

Dr. S. H. Levine, Professor, Nuclear Engineering and Director,
Breazeale Nuclear Reactor

Mr. E. J. Ney, Manager, Special Projects, Westinghouse Astronuclear
Laboratory

Dr. W. W. Pratt, Professor, Physics

Dr. G. E. Robinson, Associate Professor, Nuclear Engineering
(Present Chairman)

Dr. W. F. Witzig, Professor, Nuclear Engineering and Department
Head, Nuclear Engineering (Past Member)

Dr. G. M. Faeth, Professor, Mechanical Engineering (New member)

Dr. B. R. Parkin, Professor, Aerospace Engineering (New Member)

Dr. F. J. Remick, Associate Professor, Nuclear Engineering (New Member)

* Licensed Operator

** Licensed Senior Operator

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III. ADMINISTRATION

The permanent Facility Staff lost the services of Miss Kathy Brooks, who left in April 1975 for marriage to Mr. Robert Jabs, a 1974 graduate of the Nuclear Engineering M.S. program. Another change which did not actually occur in this report period, but which is anticipated, is the retirement of Mr. Joseph Gauthier, after 28 years with the University, 16 of which were at the Reactor Facility.

Note that the organization chart no longer shows G. E. Robinson as Assistant Director, Research. This reflects Dr. Robinson's increasing involvement with teaching, and his project responsibilities at the Applied Research Laboratory.

The group of ERDA trainees (R. H. Arnold, J. R. Bailey, G. W. Houston, and J. T. Seebald) who were involved extensively both in Reactor operation and various tours, left the operating staff as they completed their academic program. Mr. J. W. Martin, who served as a part time operator while pursuing a B.S. in Nuclear Engineering, graduated and left for employment with T.V.A.

The losses to the operating staff described above were offset by a number of additions. Mr. R. L. Fisher, ex Navy and currently a Nuclear Engineering undergraduate student, passed his NRC Operator Examination in September 1974. Mr. R. A. Jones, a 1972 graduate of the Nuclear Engineering Associate Degree program and an employee of Consolidated Edison at Indian Point for several years, came to the University as a B.S. degree candidate (Nuclear Engineering) and passed his NRC examination in April 1975.

Mr. L. Gardner and Mr. E. Resnick, both ex Navy and currently Nuclear Engineering undergraduate students, joined the staff as operator trainees and passed the NRC examination in June 1975.

Also in June, Miss K. M. Loughrey joined the staff as secretary-receptionist to replace Miss Brooks.

As noted in Section VI, Miss Ann Hart and Dr. K. N. Prasad resigned from the Radionuclear Application Laboratory.

The organization chart, figure 1, reflects the current status of the various positions listed.

In October 1974 changes to the charter of the Safeguards Committee were initiated to provide for periodic changes in membership. As a result of this several members left the committee when their terms expired, and Mr. Grandlund was replaced as Chairman by Dr. Robinson. New members appointed to the committee were selected to provide greater breadth in the technical expertise of the committee. These changes are shown on the personnel list of Section II.

Figure 1
ORGANIZATION CHART

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IV. FACILITY OPERATION

Tables I and II list pertinent operating statistics which give a feeling for the level of activity at the facility during the year. It is of interest to discuss certain differences between the statistics for this year and those of previous years.

Reactor operator training, which totaled 640 hours, showed an increase of more than 200 hours over the previous year. This resulted in only a half hour increase in the average per shift. However, training involves start-ups, which show up in a substantial increase in the approaching critical hours, and short, low-power level runs, which show up as a reduction in Hours Critical. Fewer hours at high power levels reduces the total megawatt hours and also the grams of U^{235} consumed. Also inherent in increased training is an increase in the number of scrams resulting from operator error. A large percentage of these scrams result from inexperience and unfamiliarity with facility procedures. The scrams are automatic shut downs caused by safety circuits designed to protect the various reactor systems from damage. Because of these safety devices, this reactor is often said to be "student-proof".

Some of the other factors affecting statistics were a reduction in the number of pneumatic transfer system samples, due to completions of a long term project, which reduced the number of samples and a reduction of long term samples using the rotating sample container, which shows as a decrease in the sample hours category.

Various graduate and undergraduate laboratory experiments used the Reactor for over 100 hours, and the 32 high school group tours resulting from the Nuclear Science Program took about 50 hours of Reactor time.

The inhouse Reactor operator retraining program set aside over 60 hours of Reactor time.

The annual fuel inspection and calibrations used all the time available during the Winter term break.

The activities of the AEC (now the Nuclear Regulatory Commission) consumed a large amount of effort by the operating staff. Negotiations on approval of the requalification plan continued throughout the year, and implementation of the program added considerably to the work load during the Fall term.

Another regulatory requirement which demanded much time and expense was the Physical Security Plan and its associated intrusion alarm system.

In addition to the above the facility was inspected by various regulatory agencies with respect to the R-2 License, the Special Nuclear Material Licenses, the By-Product License, and the Operator Requalification Plan. An inspection relative to the Physical Security Plan is likely, but has not occurred.

A second pneumatic transfer system is presently being installed at the facility. This system will be pressurized, operating with nitrogen gas and will provide sample travel times from the core to the counter of less than one second. The primary use of this system will be for the uranium prospecting experiments described in Section VI and VII.

Table 1
BREAZEALE NUCLEAR REACTOR OPERATION DATA
June 1, 1973 - May 31, 1975

	<u>1973-1974</u>	<u>1974-1975</u>
A. Hours of Critical Time		
1. Hours Critical	1,451.16	1,382.58
2. Approaching Critical	260.80	384.40
3. Adjusting Fuel	57.24	69.47
B. Number of Pulses	241	463
C. Number of Square Waves	61	69
D. Energy Produced in MWH	1,019.25	710.40
E. Grams U ²³⁵ Consumed	52.48	36.59
F. Number of Scrams		
1. Planned as Part of Experiments	36	71
2. Unplanned - resulting from		
a. Operator Error	13	18
b. System Failure	5	16
G. Number of 8 hour Shifts	386	413

Table 2
 BREAZEALE NUCLEAR REACTOR UTILIZATION DATA
 (average per shift)
 June 1, 1973 - May 31, 1975

	<u>1973-1974</u>	<u>1974-1975</u>
A. Number of Users	1.98	1.42
B. Samples or Experiments		
1. Number	10.34	6.24
2. Sample Hours	41.79	23.25
C. Reactor Usage (hours)		
1. Operating	3.75	3.35
2. Shutdown in Stand-by Condition	1.10	1.48
3. Reactor Operator Training	1.09	1.55
4. Calibration and Maintenance	.72	.36

The Cobalt Facility statistics shown in Table 3 reflect a change in the type of irradiations being performed for the various experimenters. Due to a shift toward people working in the biological areas, there were very few long term exposures. This lack of long term exposures caused a decline in the areas of Table 3 labeled Part C.

In general, the utilization of the facility over the past year is much like that of 1973-74 where there were again few long term exposures.

Table 3
COBALT-60 OPERATING STATISTICS
June 1, 1973 - May 31, 1975

	<u>1973-1974</u>	<u>1974-1975</u>
A. 1. Time adjusting Co-60 sources (hrs.)	10	7
2. Set-up Time	14	13
3. Total hours of sample runs	15,112	3,962
B. 1. Total number of samples	249	510
2. Total number of configuration changes	37	9
3. Total number of different experimenters	29	30
C. Per Day Averages		
1. Number of experimenters/day	1.4	0.72
2. Number of samples/day	5.3	2.9
3. Hours of use/day/configuration	10.4	2.7
D. 1. Total Sample Hours	42,854	14,474

Remarks:

Above statistics are based on 365 days and 4 configurations

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V. EDUCATION AND TRAINING

The Breazeale Nuclear Reactor and its staff of long experience continued their service to students and the Commonwealth through the offering of a variety of educational programs such as associate degree, undergraduate, and graduate laboratories, continuing education courses for electric utility personnel, and a number of new and recurring programs which will subsequently be summarized.

For the fifth consecutive summer, a four week institute for thirty high school teachers was conducted to prepare the teachers to offer a Nuclear Concepts course as a senior elective in their respective school districts. This past year, the Nuclear Concepts summer institute was expanded to include teachers from Alabama and Tennessee in addition to the Pennsylvania complement of teachers. Reactor staff members who were active in conducting the laboratory portion of the summer institute were Dr. W. A. Jester, John L. Penkala, Terry L. Flinchbaugh, and graduate students Pradosh Ray and Craig Gresko.

As in previous institutes, the teacher participants were encouraged to return with their high school student groups for a one day field trip to the Breazeale Nuclear Reactor. This resulted in 32 groups totaling 386 students participating in a full day of experiments with the neutron howitzer, the cobalt-60 sources, and the reactor itself. The extensive coordination and scheduling of the high school tour groups was accomplished by John L. Penkala, Terry L. Flinchbaugh and graduate students Jim Bailey and Elmer Stover. Table 5 summarizes the participation in this program.

The two year technician program leading to an Associate Degree in Nuclear Technology continued this past year with the final term of the six term program being offered at University Park during the Spring Term for twenty-eight students. One of the two laboratory courses given during the sixth term (Reactor Technology Laboratory) was taught by John L. Penkala with the assistance of Terry L. Flinchbaugh. Through the efforts of senior operators R. C. Houtz, I. B. McMaster, R. E. Totenbier, D. C. Raupach and J. H. O'Brien, the twenty-eight students in this course accrued a total of 488 man hours of console operating experience.

Mr. Robert C. Houtz assisted Dr. W. A. Jester and Dr. Ward Diethorn with the logistic of setting up laboratory equipment required to teach the second laboratory course (Nuclear Technology Laboratory) in the Associate Degree Program.

A course in the Elements of Nuclear Power Generation was taught during Spring Term by former A.E.C. trainee Michael J. Cenko. Mr. John L. Penkala served as faculty advisor for the twenty-eight associate degree students during their stay at University Park.

A requalification program for the entire reactor operating staff was completed between September and November 1974. Facility walkarounds were conducted by I. B. McMaster while R. E. Totenbier handled procedure familiarization. Various lecture topics were covered by T. L. Flinchbaugh, J. L. Penkala, and G. C. Geisler. Early in 1975, Mr. Flinchbaugh readied the requalification files for a review by Mr. Joseph Buzy of the Nuclear Regulatory Commission (N.R.C.). Upon completion of this initial review, Mr. Buzy registered his satisfaction with the requalification program and results.

In-house training performed by the reactor staff this past year resulted in Mr. R. L. Fisher and Mr. R. A. Jones, Jr. successfully completing requirements for N.R.C. reactor operators licenses. In addition, Mr. L. E. Gardner and Mr. E. L. Resnick passed their license exams at the end of June 1975.

Two industrial training programs were successfully completed this year by the staff of the Breazeale Nuclear Reactor with assistance from faculty members, G. C. Geisler, E. S. Kenney, S. H. Levine, K. K. S. Pillay, F. J. Remick, G. E. Robinson, and R. W. Granlund, J. K. Schmotzer, and M. J. Slobodien of the Health Physics staff.

The first industrial program was a two week effort for twelve Metropolitan Edison Company operators. The second program was a four week course which utilized the reactor from 0700 to 2400 each day of the course. The training was conducted for twenty-six Cincinnati Gas & Electric Company employees ranging in title from Station Operator to Plant Superintendent. As a result of this second effort, each of the twenty-six C. G. & E. Company employees received a minimum of ten meaningful startups and each employee completed a mock N.R.C. operator licensing examination consisting of an operational, written, and oral portion.

In the undergraduate nuclear engineering area, Mr. Houtz assisted in Nuclear Engineering 200; Mr. Geisler taught in Nuclear Engineering 440 and was assisted by Mr. Houtz and Mr. Cenko; Mr. Raupach aided in the the laboratory equipment setup of Nuclear Engineering 441. All the staff senior operators cooperated with Dr. Robinson in Nuclear Engineering 430 in affording the opportunity for the students to manipulate the controls of the Breazeale Reactor through a series of startups.

Graduate students in Nuclear Engineering used the Breazeale Reactor Facility in Nuclear Engineering 502A, 502B, and 502C during this past academic year. Drs. Jester and Levine were assisted extensively by Mr. Raupach. And of course, the multitude of electronic problems which arose in all areas of teaching and instruction were expertly handled by the staff electronic designer Mr. Douglas S. Vonada.

A Special Problems Research class in Horticulture 447 used the Cobalt-60 Facility for a laboratory experiment.

The Cobalt-60 Facility was used as a laboratory to demonstrate gamma radiation as a sterilant to horseflies for 18 Entomology 416 students.

A Horticulture 407 laboratory class exposed corn seeds to varying doses of gamma irradiations at the Cobalt-60 Facility to demonstrate effects of various radiation levels on plant growth.

Four students enrolled in Plant Science 400 studied the effects of various gamma radiation doses from the Cobalt-60 Facility on the germination of barley seeds and the subsequent growth of these barley seedlings as a special problem in plant science research.

A second year class of Nuclear Medical Technology students (6) spent four hours at the Reactor Facility for a lecture, tour and laboratory experiment involving the preparation and study of a Cesium-137 Barium-137m cow.

Approximately 30 Alpha Fire Company members toured the facility to familiarize themselves with hazards that might be involved in fighting a fire at the facility.

During October and November 1974, a special lecture and tour was given to approximately 50 University Police Services personnel (in small groups). The objective of this program was to provide the knowledge the officers need to carry out routine checks of the facility and to respond correctly in emergency situations.

Twenty ambulance drivers and Ritenour Health Center personnel were taken on a tour and lectured on possible casualties that might result from a radiation connected incident at the facility. Also, for their benefit, an emergency drill test was conducted by the Health Physics and Reactor staff which included a mock contaminated-injured person to test the health center facilities as well as personnel that would be involved in rescue operations.

Members of the State Police Forensic Laboratory spent some time at the facility for a tour, training in forensic chemistry and analysis of evidences submitted by Law Enforcement Agencies.

Finally, in the time honored tradition, the Breazeale Nuclear Reactor Staff continued the policy of providing information to any and all interested groups by entertaining 2,700 visitors ranging from fifth grade elementary school students to the Lt. Governor of the Commonwealth of Pennsylvania.

PARTICIPANTS IN REACTOR TRAINING PROGRAMS

<u>Name</u>	<u>Sponsor</u>	<u>Program</u>	<u>Started</u>	<u>Completed</u>
*R. L. Fisher	Breazeale Reactor	Operator Licensing	Feb. 1974	Sept. 1974
L. E. Gardner	Breazeale Reactor	Operator Licensing	Feb. 1975	June 1975
*R. A. Jones, Jr.	Breazeale Reactor	Operator Licensing	Sept. 1974	Mar. 1975
E. L. Resnick	Breazeale Reactor	Operator Licensing	Mar. 1975	June 1975
R. N. Arnold	U.S.A.E.C.	License Requalification	**Sept. 1974	Nov. 1974
J. R. Bailey	U.S.A.E.C.	License Requalification	**Sept. 1974	Nov. 1974
T. L. Flinchbaugh	Breazeale Reactor	License Requalification	Sept. 1974	Nov. 1974
G. C. Geisler	Breazeale Reactor	License Requalification	Sept. 1974	Nov. 1974
G. W. Houston	U.S.A.E.C.	License Requalification	**Sept. 1974	Nov. 1974
R. C. Houtz	Breazeale Reactor	License Requalification	Sept. 1974	Nov. 1974
S. H. Levine	Breazeale Reactor	License Requalification	Sept. 1974	Nov. 1974
J. W. Martin	Breazeale Reactor	License Requalification	**Sept. 1974	Nov. 1974
I. B. McMaster	Breazeale Reactor	License Requalification	Sept. 1974	Nov. 1974
J. H. O'Brien	Breazeale Reactor	License Requalification	Sept. 1974	Nov. 1974
J. L. Penkala	Breazeale Reactor	License Requalification	Sept. 1974	Nov. 1974
D. C. Raupach	Breazeale Reactor	License Requalification	Sept. 1974	Nov. 1974
K. E. Rudy	Breazeale Reactor	License Requalification	Sept. 1974	Nov. 1974
J. D. Seebald	U.S.A.E.C.	License Requalification	**Sept. 1974	Nov. 1974
R. E. Totenbier	Breazeale Reactor	License Requalification	Sept. 1974	Nov. 1974
D. S. Vonada	Breazeale Reactor	License Requalification	Sept. 1974	Nov. 1974
J. A. Brummer	Metropolitan Edison Co.	Research Reactor Operations	23 Aug. 1974	27 Aug. 1974
J. D. D'Isidoro	Metropolitan Edison Co.	Research Reactor Operations	16 Aug. 1974	20 Aug. 1974
R. C. Geiger	Metropolitan Edison Co.	Research Reactor Operations	16 Aug. 1974	20 Aug. 1974
D. L. Good	Metropolitan Edison Co.	Research Reactor Operations	16 Aug. 1974	20 Aug. 1974
B. Harrison	Metropolitan Edison Co.	Research Reactor Operations	23 Aug. 1974	27 Aug. 1974
J. J. Hayes, Jr.	Metropolitan Edison Co.	Research Reactor Operations	23 Aug. 1974	27 Aug. 1974
D. McGettrick	Metropolitan Edison Co.	Research Reactor Operations	23 Aug. 1974	27 Aug. 1974

* Qualified for Reactor Operator License

** Attended selected lectures during indicated period

Table 4

<u>Name</u>	<u>Sponsor</u>	<u>Program</u>	<u>Started</u>	<u>Completed</u>
C. McMullin	Metropolitan Edison Co.	Research Reactor Operations	23 Aug. 1974	27 Aug. 1974
M. A. Shatto	Metropolitan Edison Co.	Research Reactor Operations	16 Aug. 1974	20 Aug. 1974
E. Showalter	Metropolitan Edison Co.	Research Reactor Operations	16 Aug. 1974	20 Aug. 1974
R. Troutman	Metropolitan Edison Co.	Research Reactor Operations	23 Aug. 1974	27 Aug. 1974
J. Romanski	Metropolitan Edison Co.	Research Reactor Operations	16 Aug. 1974	20 Aug. 1974
B. S. Ashcraft	Cincinnati Gas & Elec. Co.	Research Reactor Operations	6 Jan. 1975	17 Jan. 1975
W. Blankenship	Cincinnati Gas & Elec. Co.	Research Reactor Operations	6 Jan. 1975	17 Jan. 1975
W. E. Boggs	Cincinnati Gas & Elec. Co.	Research Reactor Operations	6 Jan. 1975	17 Jan. 1975
J. E. Boyle	Cincinnati Gas & Elec. Co.	Research Reactor Operations	6 Jan. 1975	17 Jan. 1975
D. J. Cody	Cincinnati Gas & Elec. Co.	Research Reactor Operations	6 Jan. 1975	17 Jan. 1975
T. W. Cummins	Cincinnati Gas & Elec. Co.	Research Reactor Operations	6 Jan. 1975	17 Jan. 1975
S. J. Finnegan	Cincinnati Gas & Elec. Co.	Research Reactor Operations	6 Jan. 1975	17 Jan. 1975
J. W. Godsey	Cincinnati Gas & Elec. Co.	Research Reactor Operations	6 Jan. 1975	17 Jan. 1975
O. M. Hamilton	Cincinnati Gas & Elec. Co.	Research Reactor Operations	6 Jan. 1975	17 Jan. 1975
M. R. Helton	Cincinnati Gas & Elec. Co.	Research Reactor Operations	6 Jan. 1975	17 Jan. 1975
P. M. Higginbotham	Cincinnati Gas & Elec. Co.	Research Reactor Operations	6 Jan. 1975	17 Jan. 1975
P. C. Hoffmeier	Cincinnati Gas & Elec. Co.	Research Reactor Operations	6 Jan. 1975	17 Jan. 1975
P. Imbach	Cincinnati Gas & Elec. Co.	Research Reactor Operations	6 Jan. 1975	17 Jan. 1975
P. E. King	Cincinnati Gas & Elec. Co.	Research Reactor Operations	3 Mar. 1975	14 Mar. 1975
R. W. Link	Cincinnati Gas & Elec. Co.	Research Reactor Operations	3 Mar. 1975	14 Mar. 1975
W. A. Maas	Cincinnati Gas & Elec. Co.	Research Reactor Operations	3 Mar. 1975	14 Mar. 1975
R. Mayhugh	Cincinnati Gas & Elec. Co.	Research Reactor Operations	3 Mar. 1975	14 Mar. 1975
D. M. McNeal	Cincinnati Gas & Elec. Co.	Research Reactor Operations	3 Mar. 1975	14 Mar. 1975
R. G. Morgan	Cincinnati Gas & Elec. Co.	Research Reactor Operations	3 Mar. 1975	14 Mar. 1975
R. W. Pearce	Cincinnati Gas & Elec. Co.	Research Reactor Operations	3 Mar. 1975	14 Mar. 1975
J. R. Schott	Cincinnati Gas & Elec. Co.	Research Reactor Operations	3 Mar. 1975	14 Mar. 1975
T. C. Shannon	Cincinnati Gas & Elec. Co.	Research Reactor Operations	3 Mar. 1975	14 Mar. 1975
D. Smith	Cincinnati Gas & Elec. Co.	Research Reactor Operations	3 Mar. 1975	14 Mar. 1975
G. E. Sommers	Cincinnati Gas & Elec. Co.	Research Reactor Operations	3 Mar. 1975	14 Mar. 1975
J. J. Wald	Cincinnati Gas & Elec. Co.	Research Reactor Operations	3 Mar. 1975	14 Mar. 1975
R. E. Williams	Cincinnati Gas & Elec. Co.	Research Reactor Operations	3 Mar. 1975	14 Mar. 1975

Table 4 (Continued)

<u>Name</u>	<u>Sponsor</u>	<u>Program</u>	<u>Started</u>	<u>Completed</u>
J. F. Adams	Pennsylvania State Univ.	Nuclear Engr. Technology	14 Mar. 1975	21 May 1975
J. A. Bennett	Pennsylvania State Univ.	Nuclear Engr. Technology	14 Mar. 1975	21 May 1975
G. E. Burket	Pennsylvania State Univ.	Nuclear Engr. Technology	14 Mar. 1975	21 May 1975
J. G. Dallasen	Pennsylvania State Univ.	Nuclear Engr. Technology	14 Mar. 1975	21 May 1975
D. J. DeStefano	Pennsylvania State Univ.	Nuclear Engr. Technology	14 Mar. 1975	21 May 1975
R. A. Dudics	Pennsylvania State Univ.	Nuclear Engr. Technology	14 Mar. 1975	21 May 1975
L. W. Dunlap	Pennsylvania State Univ.	Nuclear Engr. Technology	14 Mar. 1975	21 May 1975
K. Eichenlaub	Pennsylvania State Univ.	Nuclear Engr. Technology	14 Mar. 1975	21 May 1975
L. A. Fisher	Pennsylvania State Univ.	Nuclear Engr. Technology	14 Mar. 1975	21 May 1975
H. E. Garman	Pennsylvania State Univ.	Nuclear Engr. Technology	14 Mar. 1975	21 May 1975
R. E. Gibney	Pennsylvania State Univ.	Nuclear Engr. Technology	14 Mar. 1975	21 May 1975
C. E. Glisan	Pennsylvania State Univ.	Nuclear Engr. Technology	14 Mar. 1975	21 May 1975
W. D. Herman	Pennsylvania State Univ.	Nuclear Engr. Technology	14 Mar. 1975	21 May 1975
L. P. Hydrick	Pennsylvania State Univ.	Nuclear Engr. Technology	14 Mar. 1975	21 May 1975
J. A. Iorii	Pennsylvania State Univ.	Nuclear Engr. Technology	14 Mar. 1975	21 May 1975
D. P. Kitzmiller	Pennsylvania State Univ.	Nuclear Engr. Technology	14 Mar. 1975	21 May 1975
D. J. Knisely	Pennsylvania State Univ.	Nuclear Engr. Technology	14 Mar. 1975	21 May 1975
L. A. Kuczynski	Pennsylvania State Univ.	Nuclear Engr. Technology	14 Mar. 1975	21 May 1975
E. C. McCready	Pennsylvania State Univ.	Nuclear Engr. Technology	14 Mar. 1975	21 May 1975
S. P. Newman	Pennsylvania State Univ.	Nuclear Engr. Technology	14 Mar. 1975	21 May 1975
M. J. Pastva	Pennsylvania State Univ.	Nuclear Engr. Technology	14 Mar. 1975	21 May 1975
P. D. Pochah	Pennsylvania State Univ.	Nuclear Engr. Technology	14 Mar. 1975	21 May 1975
W. I. Rooks	Pennsylvania State Univ.	Nuclear Engr. Technology	14 Mar. 1975	21 May 1975
J. R. Sopata	Pennsylvania State Univ.	Nuclear Engr. Technology	14 Mar. 1975	21 May 1975
E. D. Stroud	Pennsylvania State Univ.	Nuclear Engr. Technology	14 Mar. 1975	21 May 1975
J. R. Telesz	Pennsylvania State Univ.	Nuclear Engr. Technology	14 Mar. 1975	21 May 1975
G. R. Traister	Pennsylvania State Univ.	Nuclear Engr. Technology	14 Mar. 1975	21 May 1975
M. E. Wills	Pennsylvania State Univ.	Nuclear Engr. Technology	14 Mar. 1975	21 May 1975

Table 4 (Continued)

Table 5

HIGH SCHOOL NUCLEAR SCIENCE PROGRAM 1974-1975

<u>High School</u>	<u>Instructor</u>	<u>No. of Students</u>
A. W. Beatie Tech.	Mr. Leseck	14
Westinghouse Explorer	Mr. Sivi	47
Scouts, Post 258		
Penn Hills	Ms. Szitas	3
Daniel Boone	Mr. Tobias	6
Wyomissing Area	Mr. Bell	14
Lower Dauphin	Mr. Lyter	15
Altoona	Mr. Bonghi	6
Jersey Shore	Mr. Allen	9
Carlisle	Mr. Kauffman	12
Dunmore	Mr. Gatto	18
Chestnut Ridge	Mr. Popp	14
Exeter	Mr. Murray	9
Penn Hills	Ms. Szitas	7
Berwick	Mr. Foster	19
Riverside	Mr. Modzelesky	13
Titusville	Mr. McQueer	2
Troy	Mr. Johnson	10
Brownsville	Mr. Novotney	9
St. Clair	Mr. Greenway	17
Bellefonte	Mr. Young	20
Bishop O'Reilly	Sr. Cossman	6
Penn Crest	Mr. Good	13
West Perry	Mr. Stoops	13
Harbor Creek	Mr. Peterson	11
Parkland	Mr. Eckensberger	14
N. Schuylkill	Mr. Welker	5
Greater Latrobe	Mr. Eckert	9
West Jefferson	Mr. Farrell	10
Pottsville	Mr. Naradko	9
Hollidaysburg	Mr. Rhodes	18
Saucon Valley	Mr. Bordy	6
<hr/> 32 total groups		<hr/> total participants 386

NON HIGH SCHOOL GROUP.

Bucknell University	Dr. Austin	8
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VI. RADIONUCLEAR APPLICATIONS LABORATORY

The 1974-75 year has been a year of completions and change, both in programs and personnel. In August Miss Anne Hart, Engineering Aid, left the group to begin her masters degree program in microbiology. In October Dr. K. N. Prasad, Research Assistant, left the group to join Westinghouse. In June Mr. Dale C. Raupach, Reactor Supervisor, was assigned to spend up to half time working with the laboratory, assisting university researchers in utilizing the research facilities of the Breazeale Nuclear Reactor and its Radionuclear Applications Laboratory. There has been a complete change-over of graduate students with three completing their theses and four leaving with their theses in the final stage of completion.

During the course of the year, the large forensic effort of the laboratory came to an end with the completion of the third year of support from the Governor's Justice Commission. The biomedical program also was terminated for the time being with the completion of a contract from the Pennsylvania Science & Engineering Foundation. Proposals have been written in both areas to try to reestablish these efforts. Support has continued from members of the Eastern Utilities for the development of high sensitivity air and waterborne radiation monitors as well as continued support from the U.S. Department of Interior through the University's Institute for Research on Land and Water Resources to continue the development of techniques for the use of non-radioactive but neutron activatable tracers for studying the movement of underground waters.

Some of the more notable activities of the laboratory personnel include the organization of a two-day workshop by Dale Raupach to instruct University research personnel in the use of non-radioactive but neutron activatable tracers as a research tool. Drs. Prasad, Jester and Levine, and Mr. Schmotzer and Mr. Slobodien in addition to Mr. Raupach taught in this workshop. A total of 13 researchers; 5 graduate students, and 8 members of the faculty and staff were in attendance.

One of the most significant new service projects begun during the year was working with Dr. M. L. Keith and Dr. A. W. Rose of Geochemistry in developing techniques for the detection of trace amounts of uranium in stream sediments and waters as a means of detecting upstream uranium deposits. This technique involves the detection of delayed neutrons from uranium fission. This project is part of a much larger program involving three Energy Research and Development Administration (ERDA) national laboratories which will result in a nationwide search for new uranium deposits. One of the new facilities that is being installed at the PSBR as part of this project is a rapid pneumatic sample transit system to get irradiated samples from the reactor core to the detector system in less than one second.

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VII. FACILITY RESEARCH UTILIZATION

Research continues to utilize the major portion of the available operation time of the reactor and the Cobalt-60 Facility. A wide variety of research projects are currently in progress as indicated on the following pages. For convenience, the University oriented research projects are divided into three categories: research projects utilizing the PSBR, research projects involving the Nuclear Applications Laboratory (and in most cases the reactor), and research utilizing Auxiliary Radiation Sources such as the Cobalt-60 Facility. In addition, a section is provided on non-University research projects utilizing the Facility.

The Facility continues to serve as a research tool available to all faculty and graduate students of the various departments and colleges within the University. Fifty faculty members and thirty-seven graduate students have used the Facility in the past year for research. This represents a usage by eighteen different departments of the University. Names of the individual users and their departmental affiliation are given in Appendix A.

The following list of current research projects (arranged in alphabetical order using author's names) indicates the broad utilization enjoyed by the Nuclear Reactor Facility. The examples cited are not to be construed as publications or announcements of research. The publication of research utilizing the Facility is the prerogative of the researcher.

A. University Research Utilizing the Penn State Breazeale Nuclear Reactor (PSBR)

1. The Partitioning of Several Rare Earth Elements in Silicate Melt-Silicate Crystal Systems at High Temperatures and Pressures

Dr. C. W. Burnham, Geosciences Department, Dr. A. W. Rose, Jr., Mineral Conservation Section, and R. T. Flynn, Research Assistant, Geochemistry Department

The role of pressure, temperature and composition in the fractionation of the rare earths is being experimentally examined via a radioactive tracer technique. Theoretically, the fractionation should be affected by all three variables and each is being independently controlled. Current research has centered on the behavior of ^{140}La ($t_{1/2} = 40.23$ hr) and ^{153}Sm ($t_{1/2} = 46.8$ hr) in aqueous fluid-silicate melt systems. The nuclear reactor was utilized to obtain the aforementioned isotopes for use in the experiments. In addition to standardizing the experimental and analytical techniques the work has revealed the following:

- a. The partitioning in an aqueous fluid-silicate melt system is greatly shifted towards the silicate melt. Partition coefficients are in the range of 40-50:1 (concentration of melt: concentration of aqueous fluid).
 - b. In the system examined La and Sm appear to behave similarly.
 - c. Experimentally, the rare earths of the aqueous phase are mechanically swept up into a solid quench-phase; a fact not previously taken into account. Thus, this seemingly "solid" phase must be added to the aqueous phase to get meaningful results.
2. Some Aspects of Sodium and Water Balance in the Sea Snake Pelamis and the Terrapin Malachemys.

Dr. W. A. Dunson and Research Assistant G. D. Robinson of the Biology Department

Recent work on sea snakes demonstrated that the salt gland might be less important than expected in overall ion and water balance in some species. Thus we decided to initiate comparative Na and water balance studies on the yellow-bellied sea snake (Pelamis), which has a large salt gland, and on the terrapin (Malachemys), which has a smaller gland. These data are not yet completely analyzed nor have the experiments been completed. Two striking findings were obtained:

- a. The skin of Pelamis is impermeable to Na, but permeable to water. The outer keratin layer (the shed skin) is the main barrier to Na movement. Differences in skin permeability to water may be postulated among sea snakes with salt glands of different sizes.
- b. The terrapin adapts very slowly to high salinity water and has a rather complex set of physiological responses to dehydration. The skin is impermeable to Na. Terrapins that have been in sea water for months often do not have an active salt gland. Increased Na-K ATPase levels are directly related to plasma Na concentration and bladder urine K concentration. The data suggest that Na is reabsorbed from the bladder to facilitate water conservation and that the salt gland functions only when dehydration is severe. These data may support the hypothesis first put forward by Schmidt-Nielsen et al. (1963) that salt gland excretion is closely linked to urinary water reabsorption. Body fluid volume measurements have confirmed Thorson's (1968) finding that terrapins possess an extraordinarily large interstitial fluid volume. It is hypothesized that a gradual utilization of water "stored" in this compartment occurs as terrapins dehydrate in sea water.

All studies on Na influx utilized NaCl activated at the reactor facility.

3. Imaging with Scattered Thermal Neutrons

Dr. A. M. Jacobs, Dr. E. S. Kenney and U.S. Navy funded C. A. Johannesmeyer, of the Nuclear Engineering Department

Recent developments in pseudo-holography provide the means to generate a three-dimensional image of an object from any radiation it scatters. One promising technique uses scattered radiation to cast shadows of a Fresnel zone plate, referred to as the coded image, which are recorded on film. The coded image is then decoded by passing coherent light through it which is diffracted producing an image of the radiation source.

This project is devoted to developing a scattered neutron flux source function by diffusion theory methods for a non-reentrant, steady state, homogeneous body of simple geometry. To test the accuracy of the source function, the computed scattered flux is compared with some measured values. The comparison supports the diffusion approximation for detection methods which do not have a strong forward detecting preference.

4. Dynamic Radiography Using Thermal Neutrons

Dr. A. M. Jacobs, Dr. E. S. Kenney, and Graduate Assistant
P. J. Rose of the Nuclear Engineering Department

Dynamic nondestructive inspection of optically opaque systems can be accomplished using a dynamic radiography technique with thermal neutrons as the illuminating radiation. Dynamic radiography correlates the useful information in scattered radiation from vibrating objects. The information generally takes the form of three-dimensional frequency spectra profiles. Such data give the mechanical condition of objects. Thermal-neutron scattering from eccentrically rotating plastic pegs shows that single-point system correlation sensitivity can indicate the presence of pegs 1/16 in. in diameter. Pulsed polyethylene cube experiments emphasize the effects of object non-rigidity on correlation to show how sensitive dynamic-neutron radiography is to changes in the mechanical quality of nonrigid hydrogenous materials.

5. Thermal Neutron Imaging Using Coded Apertures

Dr. A. M. Jacobs, Dr. E. S. Kenney, and Graduate Assistant
P. J. Rose of the Nuclear Engineering Department

The formation of pseudo-holograms using scattered thermal neutrons and coded apertures of cadmium gratings is being investigated. The neutron-photon converter screen employed dictates about a 20 mil resolution and various test objects with such structure detail are being used.

6. Effect of Welding Fume Inhalation on Immune Response in Mice

Dr. R. E. Keith, Industrial Engineering Department, Dr. A. Zarkower, Veterinary Science Department, and Dr. W. A. Jester, Nuclear Engineering Department

Research will consist of determining the effects of controlled exposures of laboratory animals to fumes from selected welding processes on the ability of the organisms to resist subsequent infections. This is one method of evaluating the industrial occupation hazards associated with welding processes. The experiments were done to see whether and how the technique could be used to characterize welding fluxes and fumes.

The reactor facility's pneumatic transfer system was used for preliminary neutron activation analysis.

7. Delayed Neutron Spectrum Measurements Using Carrier Gas Separation of Precursors; Bromine Isotopes

Dr. E. S. Kenney and Graduate Assistant P. Ray of the Nuclear Engineering Department

The spectrometry of delayed neutrons has lagged behind other important nuclear measurements. The difficulties in separating individual precursors as well as the usual difficulties associated with fast neutron spectrometry account for this lag. Our research has progressed to the point where bromine can be effectively separated and the various isotopes studied. Our energy measurements demonstrate agreement with the foremost workers in the field as to principal energy lines, but not exactly as to magnitude of distribution over energy space. The experiment utilized the reactor coupled to the central beam tube with the heavy water collimator.

8. Neutron Multipliers for 252-Cf Neutron Sources

Dr. S. H. Levine, Dr. W. A. Jester, and Graduate Assistant B. W. Lee of the Nuclear Engineering Department

An optimization program to study the multiplication of 252-Cf neutron sources in a subcritical assembly has been completed. Analytical techniques using computer codes LEOPARD, CITATION, FOG, and EXTERMINATOR II were developed to obtain the optimum design parameters for the assembly. Experiments were performed using the TRIGA reactor as a subcritical assembly at different known K_{eff} 's to multiply a 252-Cf neutron source in well defined geometries so that the thermal neutron flux could be measured and compared with the analytical results. Excellent agreement was obtained between the measured and calculated values of the thermal fluxes for the various K_{eff} 's.

9. Novel Methods for Multiplying 252-Cf Neutron Sources

Dr. S. H. Levine and Graduate Assistant B. W. Lee of the Nuclear Engineering Department

A new concept for increasing the 252-Cf source intensity by using either the 238-U fast fission reaction or the 9-Be (n, 2n) reaction has been studied. In particular, the 238-U fission reaction has been used to increase the neutron source intensity in the TRIGA core by surrounding the 252-Cf source with depleted U cylinders. The increase in source intensity was measured to be approximately 7%. A Monte Carlo calculation verified these results. Inherent in this technique is a new method for measuring the product of $\overline{v\sigma}_f$ for 238-U averaged over a 252-Cf spectrum.

10. Fast Flux and Cross Section Measurement by Unfolding

Dr. S. H. Levine and Ph.D. Candidate J. K. Schmotzer of the Nuclear Engineering Department

The fast neutron spectrum in the PSBR is approximately defined by multi-group integral fluxes furnished by General Atomic. An activation method has been developed which will allow measurement of the shape and magnitude of the fast flux, $\phi(E)$, in and near the core.

By measuring the activity of a material activated with fast neutrons one obtains a numerical value for the expression

$$\alpha_i = \int_0^{\infty} \sigma_i(E) \phi(E) dE$$

where the subscript i refers to a particular reaction. If this is done for several different reactions whose cross section, $\sigma_i(E)$, are well known, then numerical methods known as unfolding may be used to obtain $\phi(E)$. A major portion of this project has been devoted to the development of an unfolding method which is superior to others described in the literature.

Measurements of α_i have been made for twelve different reactions at eight points in the central thimble from 2-1/2 to 23-1/2 inches above the core centerline. These reactions include:

24-Mg(n,p)24-Na
 27-Al(n, α)24-Na
 27-Al(n,p)27-Mg
 46-Ti(n,p)46-Sc
 56-Fe(n,p)56-Mn
 55-Mn(n,2n)54-Mn
 58-Ni(n,p)58-Co
 60-Ni(n,p)60-Co
 59-Co(n, α)56Mn
 90-Zr(n,2n)89-Zr
 115-In(n,n')115m-In
 197-Au(n,2n)196-Au

Once the data for the neutron spectrum at various locations has been unfolded, this data may be used to unfold cross sections using

$$\alpha_i = \int_0^{\infty} \sigma(E) \phi_i(E) dE$$

Activation rates for the reactions

have been measured in preparation for cross section unfolding.

11. Archaeological Investigation of Kaminaljuyu, Highland Guatemala

Dr. J. W. Michels and Graduate Assistant L. H. deMendoza of the Anthropology Department

Obsidian hydration dating is an important chronometric technique for archaeologists in those areas of the world where obsidian was used in the manufacture of tools. Hydration rates vary as a consequence of variation in temperature (ambient) or of variation in chemical composition. Within a homogeneous climatic region it is therefore necessary to calculate different hydration rates for different compositional types of obsidian. Discovery of compositional variation among archaeologically recovered obsidian is therefore vital to the dating process.

As a result of earlier neutron activation analysis (sodium and manganese contents) of obsidian from Kaminaljuyu, Guatemala we had learned that the principle compositional type of obsidian came from a geologic source (El Chayal) only a few kilometers from this important ceremonial and administrative center. A hydration rate was established for this type of obsidian and dating efforts have been successful. It was, however, necessary to discover whether or not this same compositional type was being used at sites on the periphery of the sustaining area of Kaminaljuyu, or whether other geologic sources of obsidian were being exploited. Only then would we know whether or not the existing hydration rate could be applied to these sites, or whether new rates would have to be established.

12. Evolution of the Axumite Kingdom, Ethiopia

Dr. J. W. Michels and Graduate Assistant L. H. deMendoza of the Anthropology Department

Obsidian, when available, invariably serves as an important commodity in long distance trade among pre-Iron Age populations. Identification of the geologic source of obsidian artifacts recovered from archaeological sites generally reveals the basic outline of trade routes that operated during pre-historic and early historic time. Since trade often plays an important role in the evolution of political systems, identification of trade routes is indispensable to archaeological research into the evolution of complex societies.

Neutron activation analysis of obsidian has proven to be a reliable means by which to identify the geologic source of such artifacts. The nuclear reactor is used to measure the amount of sodium and manganese in each archaeological specimen, and in samples from all available obsidian flows. Both the amounts and the computed ratios are used in identification studies.

In this particular case, 226 obsidian artifacts from over 70 different archaeological sites in Tigre Province, Ethiopia were analyzed. Ten different geologic sources were identified and the trade network for the Axum Civilization was greatly clarified.

13. Fission Track Investigation in Minerals and Glasses from Diatreme Bodies and Crypto-Explosion Structures

Dr. L. J. Piloni of the Physics Department and Dr. D. P. Gold of the Geosciences Department

Fission track diameters and densities are studied in minerals (principally apatite, zircon, micas, perovskite, sphene and garnets) from diatreme breccia bodies, in order to determine something about their emplacement history and age.

Spontaneous and induced fission events (tracks) are counted in etched mineral separates and glass, that have been appropriately mounted, ground, polished and etched by chemical solvents. Spontaneous and induced track diameters are compared to ascertain possible annealing of the material. In controlled annealing experiments, a plot of reduction of track density versus reduction in track diameter yields calibration curves for adjusting the calculated fission track age for annealing effects.

The technique for determining trace amounts of uranium, boron, lithium, and nitrogen in minerals with plastic detectors is also being investigated.

14. A Low Intensity Gamma Ray in the Decay of 85-Sr

Dr. W. W. Pratt of the Physics Department

One of the earliest studies of the decay of 85-Sr was carried out in the laboratory using a NaI gamma ray spectrometer. This study revealed the presence of a weak gamma ray at 878 (112) Kev which has recently been called into question. The present work was undertaken to resolve this question. It involves a study of the 85-Sr gamma ray spectrum using a 40 cm³ Ge(Li) spectrometer and has indicated a gamma ray at 868 Kev with an intensity close to that found in the earlier work. On the basis of careful half life measurements extending over a period of over a year and of measurements using an enriched 84-Sr isotope for source production, it is concluded that this transition is definitely in 85-Sr as found in the earlier work.

15. Decay of 95-Zr and 97-Zr

Dr. W. W. Pratt of the Physics Department

The gamma ray spectrum of these isotopes are being studied with a 40 cm³ Ge(Li) gamma ray spectrometer. The detection of weak transitions would help to resolve discrepancies in the assignment of levels in 95-Nb in the regions of 700-800 Kev and in 97-Nb in the region of 1350 Kev.

16. Gamma Ray Spectrum of 115m-Cd

Dr. W. W. Pratt of the Physics Department

A study of this isotope using a 40 cm³ Ge(Li) gamma ray spectrometer is being carried out to search for weak gamma rays in addition to those already firmly established. Tentative evidence for six such gamma rays has been found to date.

17. Weak Transitions in the Decay of 175-Hf

Dr. W. W. Pratt of the Physics Department

The electron capture decay of the 175-Hf leads to several excited states in 175-Lu. A study of 175-Hf, using a 40 cm³ Ge(Li) gamma ray spectrometer, is in progress to search for weak transitions. Tentative evidence has been found to date for several such transitions.

18. A Study of Short Lived Isotopes Using a Pulsed Neutron Beam

Dr. W. W. Pratt and Graduate Assistant J. A. Herritt of the Physics Department

This experiment is designed to produce short lived isotopes through neutron activation of targets placed in the beam when the TRIGA reactor is pulsed. Studies are being carried out to determine a beam geometry and shielding configuration which will give a suitable signal to background ratio. The first experiment to be undertaken is a measurement of the gamma ray spectrum from the 20 msec isomer of 24-Na.

19. Radiation Therapy Using Neutron Activated Gold Seeds

J. A. Stryker, M.D., K. L. Miller and D. W. Cambell of the Hershey Medical Center and Dr. W. A. Jester and D. C. Raupach of the Nuclear Engineering Department.

Platinum coated gold seeds doubly encapsulated in polyethylene were irradiated at the reactor facility to produce a specified amount of radioactive gold. The activated gold seeds were shipped to the Hershey Medical Center for interstitial implantation as part of radiation therapy.

B. University Research Projects Utilizing the Radionuclear Applications Laboratory

1. Effect of Clearcutting on Snow Hydrology of Small Forested Basins

Dr. D. L. DeWalle and Graduate Assistant I. G. Peters of the School of Forest Resources and Dr. W. A. Jester, of the Nuclear Engineering Department

The purpose of this work is to determine whether or not neutron interaction with water molecules can be used to develop a method of monitoring accurately the daily changes in snowpack water.

Neutrons thermalized by interaction with water will produce increasing count rate as the path length through water (snowpack) increases. A plateau will be reached, however, where count rate begins to decline with further increases of path length.

Preliminary tests of the concept with attempts to resolve changes of 1 mm of water have been conducted, and the technique seems promising.

2. Clathrate Use for the Storage of Krypton-85

Dr. W. S. Diethorn and Graduate Assistant S. Somma of the Nuclear Engineering Department

The purpose of this research is to determine the effect of radiation on the stability of krypton clathrate of hydroquinone. If radiation damage to the clathrate causes the clathrate to release the krypton, the potential use of clathrate for storage of krypton-85 is limited.

As part of this project, an attempt was made to synthesize a mixed clathrate of oxygen and argon. Activation analysis was successfully used to determine the amount of argon in the clathrate.

3. The Development of an Environmental Monitoring System for Continuous Detection of Airborne Radioactive Gases

Dr. W. A. Jester and Graduate Assistant R. H. Jabs, P. C. Newcomb, E. K. Stover, and S. Pandey of the Nuclear Engineering Department

A system for the detection of radioactive gases was constructed based on the concept of concentrating the gases by compressing them about a large NaI(Tl) detector followed by on-line gamma ray spectroscopy. This system was field tested at the Oyster Creek Nuclear Generating Station. Although this system offered a potential sen-

sitivity of about 10^{-9} to 10^{-10} $\mu\text{Ci/ml}$, its inability to resolve the complete spectrum into individual gamma peaks limited its usefulness. This current year, a second system has been built around a high resolution Ge(Li) detector to overcome the resolution limits of the first system. As with the first system, the current system was calibrated using crystals of krypton and argon clathrates irradiated in the PSBR. The current system will soon be field tested at one or more nuclear power plants.

4. The Removal of SO_2 and NO_x from Flue Gas Using Gamma Radiation

Dr. W. A. Jester, Dr. K. K. S. Pillay, M. A. Schultz and Graduate Assistants R. H. Klinetob and W. G. Runte of the Nuclear Engineering Department

The major focus of this project is the investigation of the radiochemistry of gaseous systems containing SO_2 and NO_x to obtain a better understanding of the radiochemistry of flue gas irradiated by gamma radiation. Previous work by the authors and others has indicated to the authors the possibility of using the radioactive waste of the nuclear industry to remove these pollutants from the flue gas resulting from the burning of fossil fuel. When SO_2 is irradiated in the presence of NO_x , O_2 , hydrocarbons, etc., a myriad of ionic and free radical forms ensues, resulting in reactions which convert much of the SO_2 and NO_x into innocuous or easily removed forms. The objectives of this project encompass two major thrusts:

1. The investigation of SO_2 - NO_x radiochemistry reactions with other known components of flue gas to determine the optimum conditions to promote these reactions and
2. The irradiation of raw flue gas systems which set a standard against which the results from the irradiation of individual mixtures of gases are compared.

To date the radiochemistry of pure SO_2 , $\text{SO}_2 + \text{O}_2 + \text{H}_2\text{O}$ (vapor) have been studied. Currently the radiochemistry of $\text{SO}_2 + \text{N}$ and $\text{SO}_2 + \text{NO}_2$ is being studied.

5. Evaluation of Silver Zeolite for the Collection and Detection of Radioactive Iodine from the Atmosphere

Dr. W. A. Jester, Dr. K. N. Prasad and Graduate Assistant V. R. Burke of the Nuclear Engineering Department

One of the major concerns of the Nuclear Regulatory Commission (NRC) is the emission of radioactive iodines from nuclear power plants. Such radioiodine can readily enter the food chain, especially in milk where it can expose the population, especially

young children, to thyroid radiation doses. Because of this potential problem, the NRC, in its "low as practicable" concept, has set emission limits to such a low level that it is difficult to detect with current methods of detection. The object of this effort was to evaluate a particular type of iodine absorbing material called "Silver-X" a silver zeolite, as a medium to concentrate a measurable amount of radioactive iodine out of a large volume of air for subsequent monitoring.

After preliminary testing of this material using ^{128}I produced with the PSBR, a test apparatus has been constructed using one bed of glass wool as a dust absorber, two beds of Silver-X and one bed of graphite. This apparatus will soon be field tested at an operating nuclear power station.

6. The Production and Evaluation of $^{85\text{m}}\text{Kr}$ as a Lung Scanning Agent

Dr. W. A. Jester and Dr. K. N. Prasad of the Nuclear Engineering Department and Dr. G. L. Jackson of the Hershey Medical Center

A previous investigation of nuclear properties revealed that $^{85\text{m}}\text{Kr}$ had several desirable characteristics for use in lung scanning when compared with ^{133}Xe , the agent most currently in use. These include a more desirable photon energy and a lower patient dose. A novel approach was utilized for the production and delivery of the radioactive gas. This involved irradiating krypton in the form of its hydroquinone clathrate crystals. This approach avoided problems usually encountered in handling radioactive gases. A successful animal test produced lung scans showing the superior properties of the $^{85\text{m}}\text{Kr}$ over ^{133}Xe . A program to provide this material to Pennsylvania hospitals has been proposed to the Pennsylvania Department of Health.

7. Identification and Evaluation of Water Traces Amenable to Post-Sampling Neutron Activation Analysis

Dr. W. A. Jester of the Nuclear Engineering Department and K. A. Uhler, Ph.D. Candidate of the Civil Engineering Department

This year saw the completion of the study of potential non-radioactive but neutron activatable water tracers. This work confirmed the previous work, indicating that the bromide ion analyzed as ^{128}I worked well under all conditions but very low pH's and had a better detection sensitivity than the ^{80}Br . The chloride ion analyzed as ^{38}Cl also survived well under all evaluated conditions but suffered from the high chloride background in most waters. The cobalt as the ion analyzed as $^{60\text{m}}\text{Co}$ survived well in most soils at pH's of 5 and 3 but did poorly at a pH of 7 and in some types of soils

at all pH's. There was also the problem of extracting cobalt from the soil. The vanadate ion analyzed as 52-V survived well with most soils only at a pH of 3.

The first full scale trial for the use of dual tracers was conducted to evaluate ground water movement in the vicinity of a large limestone mine. Water pumped from the mine was successfully traced and the amount being recirculated into the mine by two different routes was determined. The dual tracer techniques are going to be used to study water movements in a large watershed area with the cooperation of the Northeast Watershed Research Center of the U.S. Department of Agriculture.

8. Environmental Pollutants in Tissues and Lice of the Northern Fur Seals

Dr. K. C. Kim of the Entomology Department and Dr. W. A. Jester of the Nuclear Engineering Department

Environmental pollutants including heavy metals, pesticides and various radionuclides have been found in every trophic level of the marine ecosystem. The objectives of this study are to determine and monitor the levels of these pollutants in various tissues and ectoparasites of marine mammals and to study morphological and physiological conditions of marine mammals in relation to the levels of trace environmental pollutants.

A series of these samples were subjected to radiation counting in a high resolution gamma ray spectrometer in an attempt to identify any radionuclides which may have been accumulated in these tissues and parasites. None have been detected to date.

9. Neutron Activation Analysis of Prehistoric and Contemporary Pottery and Clays from the Area of Guatemala City, Guatemala

Dr. F. R. Matson and Ph.D. Candidate P. M. Rice of the Anthropology Department and Dr. W. A. Jester of the Nuclear Engineering Department

Neutron activation analysis was undertaken as part of a study of pottery in the highlands around Guatemala City, Guatemala. "White" pottery is made by contemporary potters in several villages north of the city, and "white" pottery is found throughout the archaeological ceramic sequence of the valley, particularly in Middle through Terminal Formative times (1000 B.C. - 200 A.D.). The objective of the study was to trace back into the archaeological sequence the use of the clay sources which are presently being exploited by potters, with the hypothesis that one or more of these sources were used in pre-Conquest times. Neutron activation analysis was used to characterize the fragments of archaeological pot-

tery and samples of the clays by their trace element patterns. Clays were mixed with varying quantities of sand (temper) and fired to different temperatures to investigate the effect of these variables on trace elements. Samples were irradiated at 1 MW for two hours, allowed to decay for 14 days, then analyzed for all elements. Sixteen elements are being used in the final analysis: Mn, Fe, Co, Rb, Sb, Ba, Cs, La, Ce, Eu, Yb, Lu, Hf, Ta, Pa, and Sm.

10. Activation Analysis and Dendrochronology for Estimating Pollution Histories

Dr. K. K. S. Pillay of the Nuclear Engineering Department

This program is designed to investigate the presence of biologically active trace elements in tree-rings. So far, the analyses have been limited to the use of non-destructive neutron activation, although it is planned to include atomic absorption measurements as well as selective radiochemical analyses for the isolation and analyses of radioactive species. In addition, dendrochronological data collected on these tree-rings are used to determine the chronological sequence of the environmental history of trace elements. The accumulation or depletion of such elements in successive tree-rings can be indicative of the changes in environmental concentrations of the elements.

Various investigations conducted so far indicate that plant tissues grown through periods of varying environmental pollution levels keep permanent records of the available trace elements in the immediate environment of the plants and these records can be revealed through a systematic application of activation analysis and dendrochronological measurements. Detailed studies done on three different species (flowering cherry, yellow locust and black oak) indicate similarities between the flowering cherry and yellow locust in the observed variations of elements such as Se, Hg, Ag, Zn, Cr, Hf, Co, etc., while the black oak from the same region does not show parallel changes. It is hoped that further investigations will answer questions of species specificity that may be accountable for some of the observed differences among different plants.

11. Forensic Applications of Trace Elemental Analysis of Human Hair

Dr. K. K. S. Pillay, Dr. W. A. Jester and Graduate Assistant
R. L. Kuis of the Nuclear Engineering Department

During the past three years, the Radionuclear Forensic Studies at Penn State undertook an extensive survey of the trace elements in human hair and ether washings of hair. These analyses were done after developing two sets of analytical samples from each hair and

examining the presence and quantity of 22 different elements in each of the samples. As a result, nearly 10,000 elemental analyses data on nearly 250 hair samples were developed. In order to examine the appropriate way of using this information for forensic investigations, several statistical analysis methods were examined. A special statistical analysis method developed by Dr. J. B. Parker of the Atomic Weapons Research Laboratory at Berkshire, England was adopted and this method seems to offer the most promise in utilizing neutron activation analysis data on human hair for forensic applications.

In the analysis of trace elements of human hair, two factors make it impossible to identify positively whether a single strand (or a few strands) of hair did come from a particular individual. First, there are intrinsic variations in the trace element contents from hair of the same head. Secondly, the variation of trace element content of hair samples from the same person is compounded by experimental errors of measurement. The statistical method developed by Parker statistically qualifies whatever common features that might exist between two samples. However, it is not possible to make an absolute statement of identity based on these trace element analysis results alone.

The unique feature of the work completed at Penn State is the ability of the techniques to make determinations of environmental influences, as shown by hair's surface contaminants. These analyses can at times be of great significance in criminal investigations. Again, the data developed during this work is probably the best set of reliable data on trace element constituents of human hair, because most of the large scale surveys done prior to this investigation have experienced serious limitations due to limitations of technology available at that time.

12. Radionuclear Forensic Investigations

Dr. K. K. S. Pillay, Dr. S. H. Levine, Dr. W. A. Jester and Graduate Assistants D. C. Driscoll, S. H. Moss, R. L. Kuis and B. W. Lee of the Nuclear Engineering Department

During this year we have completed the third and final year of a research and developmental program of bringing the applications of nuclear techniques to criminal investigations. This program made significant achievements in the development of new and improved methods of gathering and analyzing evidences as well as in applying some of the methods for a number of criminal investigations.

A new method of evidence collection developed called-Film Lift Techniques-is now widely used in the Commonwealth of Pennsylvania for the collection and analysis of evidence from criminal incidents involving the use of firearms. This method has been used for the

investigation of over 150 cases in Pennsylvania and several of these have been presented in courts. Technical assistance and expert opinions have been offered to law enforcement agencies as well as to both the defense and prosecution. Several court testimonies resulted in response to subpoena issued for expert opinions.

Other accomplishments of the program include (a) The discovery of unique patterns formed on surfaces by firearm discharge residues carried in the wake of a flying bullet; (b) An extensive investigation of trace element characteristics of human hair and the development of new experimental methods and the adoption of a very practical statistical technique to utilize these data for forensic science investigations; and (c) The design of a Subcritical Assembly to multiply the neutron fluxes from 252-Cf sources and the evaluation of the potentials of these sources in forensic neutron activation analysis. These topics have been reported here previously and in other publications. Several theses resulting from this project are now being submitted in partial fulfillment of the requirements of graduate studies in nuclear engineering.

13. Application of Stable Chromium as an Activatable Tracer to Investigate the Depletion of Platelettes from Animals with Heart Assist Pumps

Dr. K. K. S. Pillay of the Nuclear Engineering Department and Dr. W. S. Pierce and Graduate Assistant J. Hart of the Hershey Medical Center

For the past several years, a major research effort undertaken at the Hershey Medical Center of the Pennsylvania State University involved the development of a pump that can relieve the heart of a major work load by relieving the major pumping chamber of all flow and pressure work associated with the stretching of muscle fibres of the heart. One of the problems encountered during this effort is the observation of the formation of thrombi as the blood-prosthesis interface with the subsequent risk of embolization. In animals into which artificial assist pumps have been introduced into the circulatory system, it is expected that platelets adhere to the layer of adsorbed protein on artificial surfaces. It has therefore become necessary to study the platelet survival time in these experimental animals to determine the value of pharmacological inhibitors used to minimize the depletion of platelets. One of the recognized methods of measuring the platelet survival time is using radioactive chromium to label the platelets. However, this procedure is not practical in large animal experimentation because of the problems associated with radioactivity in excretions and carcasses.

An alternate approach is to use enriched stable 50-Cr isotopes to label the platelets and analyze the platelets in blood samples

taken periodically using neutron activation analysis. The necessary analytical techniques for performing these studies have been developed earlier by Dr. Pillay for the study of erythrocyte kinetics in humans.

At the present time, measurements are being done on normal animals (without assist pumps) for the comparison of platelet survival time with those found in experimental animals. It is planned to perform these studies on a dozen animals, six of which will have the artificial assist pumps installed.

14. Comparison of the Head Hair Zinc Levels of Children with Learning Disabilities to Normal Populations Using Neutron Activation Analysis

Dr. K. N. Prasad, Dr. W. A. Jester and Graduate Assistant T. J. Donlan of the Nuclear Engineering Department

Zinc has been found to play a key role in many aspects of human physiology. A research project was undertaken to investigate the possible connection between abnormal zinc metabolism and learning deficiency in children. The zinc in the hair of children with a learning deficiency was compared with that in other groups of people.

The hair samples obtained were from 24 children with a learning deficiency and their relatives. Some samples from non-relatives were also obtained. The procedure for analysis consisted of washing in ethyl ether, encapsulation in quartz, irradiation in the reactor, post-irradiation preparation of sample and gamma spectroscopy with a Ge(Li) detector.

The samples were divided into four groups and the results of the analyses intercompared among them. The groups were: (a) The patients with a learning deficiency, (b) their relatives and (c) their siblings, and (d) non-relatives. It was found that: (a) There is no significant difference between the relatives as a group (including siblings) and non-relatives, and (b) there is a significant difference between the patients and their sibling relatives. Thus, there is a strong indication that lower zinc concentration in hair can be related to learning deficiency in children.

The results of the analysis are given below.

<u>Group</u>	<u>Samples</u>	<u>Concentration in ppm</u>	
		<u>Mean</u>	<u>Standard Deviation</u>
CLD	24	158	50
SIB	47	177	68
PAR	33	176	42
REL	80	177	59
NONREL	71	177	85

Where CLD Children with Learning Disabilities
 SIB Siblings of CLD
 PAR Parents of CLD
 REL Relatives of CLD, i.e. SIB + PAR
 NONREL A Group of Non-relatives

15. Development of Neutron Activation Analysis and X-ray Fluorescence Techniques for the Trace Element Analysis of Amniotic fluid

Dr. K. N. Prasad, Dr. W. A. Jester and Graduate Assistant
 W. G. Runte of the Nuclear Engineering Department

Instrumental neutron activation was investigated as a tool for the analysis of copper in amniotic fluid. This technique was not successful because of the interference of 29-Na and 38-Cl. Calcium could be detected as 44-Ca and was found to be in the order of 70 ppm for the samples analyzed. An X-ray fluorescence system was set up using a high resolution Si(Li) detector and a portable X-ray unit in an attempt to analyze for zinc in the amniotic fluid. The limit of detection for this system was found to be about 20 ppm for zinc, but this was not sensitive enough for detecting any zinc in the amniotic fluid.

16. Uranium Reconnaissance in Pennsylvania

Dr. A. W. Rose, Dr. M. L. Keith and Graduate Assistants
 R. Schmiermund, J. G. Stepanek, and J. G. Crock of the
 Geosciences Department

The research is designed to develop improved methods of regional prospecting for uranium. The reactor facility was used for trace uranium analysis by the delayed neutron method. Several hundred samples were analyzed including river water (uranium at parts per billion level) and the fine-grained fraction of stream sediments (typically with a few parts per million of uranium).

17. Neutron Activation Analysis of Cerebro-Spinal Fluid

Dr. W. A. Weidner and K. L. Miller of the Hershey Medical Center and Dr. W. A. Jester and D. C. Raupach of the Nuclear Engineering Department.

This project is designed to determine if there are neutron-activatable metallic ions (such as mercury) in cerebro-spinal fluid which may indicate manifest cerebral spinal or ventricular disease. The cerebral spinal fluid is obtained during myelography and pneumoencephalography for comparison purposes.

A pilot study is being performed on thirty samples to determine if significant differences exist which may warrant further investigations.

Currently only instrumental activation analysis is being used which limits the investigation to the longer lived neutron activation products because of the interference of Sodium-24.

C. University Research Projects Utilizing Auxiliary Radiation Sources such as the Cobalt-60 Facility

1. Phosphate and Molybdate Adsorption on Soil Oxides

Dr. D. E. Baker and Research Assistant S. B. Hornick
of the Agronomy Department

Hypothesis: To determine the effect of Soil Oxides on the adsorption of Phosphate and Molybdate anions.

Some anions are specifically adsorbed on soil colloids with the oxides contained in the soil playing a major role. The research is designed to determine how the amount of oxides contained in the soil, along with soil pH determine the adsorption of anions. Four soils containing 4 levels of oxides (1.5-9.2%) have been equilibrated with one another in an ecologen shaker with .0125M Cl solutions. It was necessary to sterilize the soils at the Cobalt-60 Facility before this equilibration (4 days) in order to prevent bacterial growth. The four soils were limed at 4 pH levels for the equilibrations. The next step in the procedure is to take samples of the 4 soils at the 4 pH levels, equilibrate separately with a salt solution (48 hrs) and then add isotopes of phosphorus molybdenum to determine the labial amounts of these isotopes in order to determine the effects of the oxides on the anion adsorption.

2. Breeding Ornamental Plants for Low Light Intensity Conditions.
Sub-project - Mutation Breeding of African Violets

Dr. R. Craig and Undergraduate R. P. Wilhelm of the Horticulture Department

Preliminary investigations involved the irradiation of African violets with several dose rates of gamma radiation at the Cobalt-60 Facility to produce mutations. Additional studies will depend upon the results of these tests.

3. Molecular Beam Scattering from Clean LiF Surfaces

Dr. D. R. Frankl and Graduate Assistant J. A. Meyers of the Physics Department

Crystals were cleaned in ultra-high vacuum to produce clean surfaces. The crystals were gamma-irradiated before mounting in order to produce defect centers that inhibit dislocation motion and thus promote good cleavage.

4. Effect of Acute Gamma Radiation on *Pediastrum boryanum*
(Turpin) Meneghini

Dr. C. L. Hillson and M. S. candidate A. J. Slavinski of
the Biology Department

Although the effects of various kinds of ionizing radiations on higher plants are fairly well established, their influence on lower plants such as algae seems, in general, to be less well known. Many algae (especially unicellular and colonial forms) would, however, appear to be very useful subjects for investigations of plant-radiation interactions, due to their structural simplicity, rapid generation time, and the fact that large numbers of individuals can be grown, and irradiated, in a small space.

The genus *Pediastrum* comprises a group of microscopic freshwater algae whose body plan is that of a small colony of cells which form a plate one cell thick, and typically are arranged in distinct geometric configurations. *P. boryanum* is currently being subjected to various acute doses of gamma radiation in the Cobalt-60 facility, in order that effects upon the growth curve, numbers of cells in colonies, and patterns of cell arrangement in colonies may be ascertained.

5. Pseudo-holography with Penetrating Radiation

Dr. E. S. Kenney, Dr. A. M. Jacobs, and Research Assistant
R. G. Sider of the Nuclear Engineering Department

To date, successful pseudo-holograms have been produced of simple objects such as metal letters and machined parts. These holograms were produced using scattered x-rays and Fresnel coded apertures. A laser has been used to re-fold these images into the usual viewing space. Research is continuing into variations to the coded masks and other coding techniques. Whereas x-rays have been used up to now, low energy gamma rays should produce better images. Research is being expanded to include the imaging of low contrast biologically important tissue structures.

6. Study of 2-Phase Flow Using a 4-Channel Dynamic Radiograph

Dr. E. S. Kenney and A. E. C. Trainee G. J. Sagliocca of the
Nuclear Engineering Department

The construction of flow and density profiles is difficult in a 2-phase flow system. Using scattered x-rays, a direct sensitivity to density gradients is achieved. By employing 4 collimated photon deflectors in 2 pairs of cross-correlated units, flow velocities between 2 selected points in a 2 phase systems could be measured. A single x-ray generator served as the photon source. Because of the low energies employed, analysis was restricted to small flow tubes of about 1 inch diameter.

7. Immunological Aspects of Coal Miner's Pneumoconiosis

R. L. Naeye, M. D., Department of Pathology, Professor and Chairman, Hershey Medical Center

It is the purpose of our project to determine if coal miners develop a cell-mediated immunologic reaction to coal dust or other substances in the mine atmosphere.

To date, we have performed lymphocyte transformation tests on blood samples from approximately 80 underground coal miners and 20 retired coal miners. These tests involve cell cultures in which we introduce suspensions of coal dust, or certain other antigens, to the lymphocytes from the miner's blood.

We made use of the Cobalt-60 source to irradiate our coal samples, thereby sterilizing the dust and rendering it suitable for cell culture purposes. Each sample absorbed at least 3-10 rads.

8. Dielectric Properties of Irradiated Barium Titanate

Dr. R. E. Newnham, Solid State Science Department, Dr. L. E. Cross, Electrical Engineering Department, and Undergraduate G. E. Berkey, Material Science Department

Barium titanate is widely used as a capacitor material. When cooled through the Curie temperature at 130°C , BaTiO_3 spontaneously polarizes and forms ferroelectric domains. Some of the walls between these domains are charged. We hoped to influence the formation of the charged walls by altering the conductivity of BaTiO_3 with gamma radiation using the Co-60 facility. Our hope was to enhance the dielectric permittivity of the material but the experiments indicated the effect is small.

9. Fast Reactor Spectrum Assembly (FRSA)

Dr. S. H. Levine, Dr. W. F. Witzig, ERDA Trainees J. D. Seebald and G. W. Houston, and Graduate Assistants F. A. Wolfe, H. E. Collins and W. R. Spears

The Fast Reactor Spectrum Assembly is a material lattice constructed of iron and graphite and designed specifically to accommodate up to 363 pathfinder fuel elements. The material composition has been selected to produce a fast neutron spectrum for the purpose of studying some spectra related parameters of the core and blanket regions of fast breeder reactors. A structural safety analysis was performed to demonstrate both the mechanical integrity of the assembly under various static and dynamic loads, and the physical protection of the fuel elements. Neutronic and structural safety analyses, as well as fuel handling and loading procedures,

were documented in an application to be submitted to the Nuclear Regulatory Commission. Several designs for a fission plate, to be used in generating the incident fast flux on the assembly, have been proposed. Mock-ups of some of the proposed designs have been constructed and tested for hermetic integrity and heat bond effectiveness. Neutron detection equipment is being procured, and the associated electronics are being developed to perform the desired gamma discrimination, pulse shaping, and digital readout.

10. A Fission Plate to be Used as a Fast Neutron Source for the Fast Reactor Spectrum Assembly

Dr. S. H. Levine, Dr. W. F. Witzig and ERDA Trainee J. D. Seebald of the Nuclear Engineering Department.

The fission plate is designed to be a doubly sealed aluminum enclosure containing about 90 grams of ^{235}U nuclei will fission and emit fast neutrons. Thus, the fission plate will be a source of fast neutrons that can be used for experimental purposes. One use of the fission plate will be as a fast neutron source for the Fast Reactor Spectrum Assembly (FRSA) located in the beam hole laboratory of the reactor facility.

An analysis of the fission plate was performed to determine the magnitude of the radiation dose rate it will produce, the type and amount of shielding that it will require, and the severity of the radiation hazard that would result if there was an accidental release of gaseous fission products from the plate.

A request for permission to construct and use the fission plate has been submitted to the P.S.U. Isotopes Committee, which will submit to the Nuclear Regulatory Commission a request for an amendment to special nuclear materials license SNM-95 that will allow construction and use of the fission plate.

The gamma ray shield and other structures to be used in connection with the fission plate were constructed in the machine shop of the Reactor Facility and transported to the Beam Hole Laboratory, where they are now located.

11. The Influence of Radiation on the Inception of Nucleate Boiling

Dr. G. E. Robinson and AEC Trainee R. H. Arnold of the Nuclear Engineering Department

The purpose of this research is to investigate the influence of radiation on the inception of nucleate boiling from a heated surface. A pool boiling system has been constructed in one of the "hot cells". Isolated bubble growth from a heated wire immersed in Freon-12 is being investigated. A comparison of the wire tempera-

tures required to initiate boiling with and without various strength Co-60 sources, beta sources and a neutron source are being made. The influence of saturated versus subcooled liquid is also being investigated.

D. Non-University Research Projects Utilizing the Facilities of the Penn State Breazeale Nuclear Reactor

The facilities of the Penn State Breazeale Nuclear Reactor (PSBR) are made available to state, federal, and industrial organizations at times which do not conflict with the University's educational and research programs. Organizations using these facilities in their research and development programs include:

Industrial Organizations

Raytheon Company

In general, Raytheon's work at the nuclear reactor consists primarily of irradiating electronic devices and in some instances electronic circuits in order to assess the damage effects on these parts due to neutron bombardment. Data from these tests are used to predict survivability/vulnerability levels of electronics equipment that might be subjected to various nuclear environments. Data is also used to aid in the design of radiation tolerant electronic equipment.

Charles Stark Draper Laboratory, Inc.

Investigation of Neutron Environment Effects on Transistors and Integrated Circuits

P. R. Kelley, Staff Engineer and R. B. Miller and J. F. Lescher

The nuclear reactor facility has been used to investigate how neutron environments effect the functional and parametric characteristics of transistors and integrated circuits. The results of this research will provide greater insight in understanding neutron sensitive damage mechanisms in integrated circuits. In addition, the studies undertaken will provide data for determining damage coefficients which will be useful for predicting circuit responses to neutron environments.

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VIII. THESES, PUBLICATIONS AND REPORTS

Theses, publications and reports pertinent to the use or operation of the Facility are listed below.

Theses

1. "Ionization of Air by Gamma Irradiation in an Electric Field," T. G. Bartholet, M. S. Theses, 1974, Nuclear Engineering Department, M. A. Schultz, Thesis Advisor.
2. "Dielectric Properties of Irradiated Borium Titanate," G. E. Berkey, B. S. Thesis, 1975, Ceramic Science Department, Dr. R. E. Newnham, Thesis Advisor.
3. "Comparison of the Head Hair Zinc Levels of Children with Learning Disabilities to Normal Populations using Neutron Activation Analysis," T. J. Donlan, M.S. Thesis, 1974, Nuclear Engineering Department, Dr. W. A. Jester, Thesis Advisor.
4. "Application Requirements for Licensing the Penn State Fast Reactor Spectrum Assembly," G. W. Houston, M. Eng. Paper, 1975, Nuclear Engineering Department, Dr. W. F. Witzig and Dr. S. H. Levine, Paper Advisors.
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6. "A Contribution to the Study of Imaging with Scattered Thermal Neutrons," C. A. Johannesmeyer, M.S. Thesis, 1974, Nuclear Engineering Department, Dr. A. M. Jacobs, Thesis Advisor.
7. "High-Intensity Gamma Irradiation of Sulfur Dioxide in Combination with Various Gases," R. H. Klinetob, M.S. Thesis, 1975, Nuclear Engineering Department, Dr. W. A. Jester, Thesis Advisor.
8. "Dynamic Radiography Using Neutrons," P. J. Rose, M. Eng. Paper, 1974, Nuclear Engineering Department, Dr. A. M. Jacobs, Paper Advisor.
9. "Application of a 4-Channel X-ray Dynamic Radiography System and Signal Correlation Techniques to the Measurement of Bubble Velocity Profiles in a Laminar Two-Phase Flow," G. J. Sagliocca, M.S. Thesis, 1974, Nuclear Engineering Department, Dr. E. S. Kenney, Thesis Advisor.

10. "The Use of Coded Aperture Techniques in the Formation of Images with Scattered Radiation," R. G. Sider, M.S. Thesis, 1974, Nuclear Engineering Department, Dr. E. S. Kenney, Thesis Advisor.
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2. "Salt and Water Balance in Sea Snakes," Biology of Sea Snakes (in press), University Park Press, Baltimore, W. A. Dunson, ed., of the Biology Department.
3. "Sea Snake Skin: Permeable to Water but not to Sodium," submitted to Biology of Sea Snakes, University Park Press, Baltimore, W. A. Dunson and G. D. Robinson of the Biology Department.
4. "Gamma Radiation Effects of the Reproduction of the Alfalfa Weevil: I. Response of Age and Sex," Turrialba 25(1): 58-66, 1975, F. R. Ferrer and A. A. Hower of the Entomology Department.
5. "Gamma Radiation Effects of the Reproduction of the Alfalfa Weevil: II. Influence of Mating Sequence and Length of Confinement on Sperm Transfer and Utilization," Turrialba 25(2): 24-30, 1975, F. R. Ferrer and A. A. Hower of the Entomology Department.
6. "Preliminary Tests of Sampling and Analytical Techniques Suitable for Regional Uranium Surveys," Progress Report to ERDA, April 1975, M. L. Keith, A. W. Rose, and N. H. Suhr of the Geosciences Department.
7. "Activation Analysis of Heavy Metals in Surface Waters using Ion Exchange Filter Papers and Cyanide Complexing," Journal of Radioanalytical Chemistry 16: 21-29, 1973, A. M. Kolaczowski and W. A. Jester of the Nuclear Engineering Department.
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11. "El Chayal, Guatemala: A Chronological and Behavioral Reassessment," American Antiquity 40, No. 1, 1975, J. W. Michels of the Anthropology Department.
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13. Film-Lift Techniques: An Instructional Manual, The Pennsylvania State University, 1974, K. K. S. Pillay of the Nuclear Engineering Department.
14. "Gunshot Residue Collection Using Film-Lift Techniques," Forensic Science 4: 145-153, 1974, K. K. S. Pillay and W. A. Jester of the Nuclear Engineering Department and H. A. Fox III of the Pennsylvania State Police.
15. "Radionuclear Forensic Investigations - Final Project Report," The Pennsylvania State University, October 1974, K. K. S. Pillay, S. H. Levine, and W. A. Jester of the Nuclear Engineering Department.
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19. "Collection and Activation Analysis of Airborne Gunshot Residues," Journal of Radioanalytical Chemistry 15: 79-85, 1973, W. B. Renfro and W. A. Jester of the Nuclear Engineering Department.
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21. "Field Test Results Using the Bromide Ion as a Neutron Activatable Tracer," Institute for Research on Land and Water Resources, The Pennsylvania State University Research Publication No. 85, 1974, J. K. Schmotzer and W. A. Jester of the Nuclear Engineering Department and R. R. Parizek of the Geosciences Department.
22. "Dietary Analysis in Granivores through the Use of Neutron Activation," Ecology, 55, No. 2: 340-349, 1974, B. W. Smigel and W. A. Jester, et al., of the Nuclear Engineering Department.
23. "Identification and Evaluation of Water Tracers Amenable to Post-Sampling Neutron Activation Analysis," Institute for Research on Land and Water Resources, The Pennsylvania State University Research Publication No. 85, 1974, K. A. Uhler of the Civil Engineering Department and W. A. Jester of the Nuclear Engineering Department.

APPENDIX A

Faculty and Staff Members Utilizing the Facilities of the
Penn State Breazeale Nuclear Reactor (Including the Cobalt-60 Facility and the Radionuclear Applications Laboratory).

Ayers, John E., B.S., M.S., Ph.D.
Associate Professor
Department of Plant Pathology
College of Agriculture

Baker, Dale E., B.S., M.S., Ph.D.
Professor
Department of Agronomy
College of Agriculture

Burnham, C. Wayne, B.A., M.S., Ph.D.
Professor
Department of Geosciences
College of Earth and Mineral Sciences

Campbell, Dale W., B.S., M.S.
Associate Health Physicist
Hershey Medical Center

Craig, Richard, B.S., M.S., Ph.D.
Associate Professor
Department of Horticulture
College of Agriculture

Cross, Leslie E., B.S., Ph.D.
Professor
Department of Electrical Engineering
College of Engineering

DeWalle, David R., B.S., M.S., Ph.D.
Associate Professor
School of Forest Resources
College of Agriculture

Diethorn, Ward S., B.S., M.S., Ph.D.
Professor
Department of Nuclear Engineering
College of Engineering

Dunson, William A., B.S., M.S., Ph.D.
Professor
Department of Biology
College of Science

Flinchbaugh, Terry L.
Reactor Supervisor, Nuclear Reactor
Department of Nuclear Engineering
College of Engineering

Frankl, Daniel R., B.Ch.E., Ph.D.
Professor
Department of Physics
College of Science

Garwood, Douglas L., B.S., M.S., Ph.D.
Assistant Professor
Department of Horticulture
College of Agriculture

Geisler, George C., B.S., M.S.
Research Associate
Department of Nuclear Engineering
College of Engineering

Gold, David P., B.Sc., M.Sc., Ph.D.
Professor
Department of Geosciences
College of Earth and Mineral Sciences

Granlund, Rodger W., B.S., M.S.
University Health Physicist
Institute of Science and Engineering

Hillson, Charles J., B.S., M.S., Ph.D.
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College of Science

Houtz, Robert C.
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Department of Nuclear Engineering
College of Engineering

Jackson, George L., B.S., M.D.
Clinical Associate Professor
Section of Nuclear Medicine, Harrisburg Hospital
Hershey Medical Center

Jacobs, Alan M., B.Engr., M.S., Ph.D.
Professor
Department of Nuclear Engineering
College of Engineering

Jester, William A., B.S., M.S., Ph.D.
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Department of Nuclear Engineering
College of Engineering

Keith, MacKenzie L., B.Sc., M.Sc., Ph.D.
Professor
Department of Geosciences
College of Earth and Mineral Sciences

Keith, Robert E., B.S., M.S.E., Ph.D., P.E.
Associate Professor
Department of Industrial Engineering
College of Engineering

Kenney, Edward S., B.S., M.S., Ph.D.
Professor
Department of Nuclear Engineering
College of Engineering

Kim, Ke Chung, B.S., M.S., Ph.D.
Associate Professor
Department of Entomology
College of Agriculture

Levine, Samuel H., B.S., M.S., Ph.D.
Professor
Department of Nuclear Engineering
College of Engineering

Matson, Frederic R., B.S., M.S., Ph.D.
Research Professor
Department of Anthropology
College of the Liberal Arts

McMaster, Ira B., B.S.
Research Assistant
Department of Nuclear Engineering
College of Engineering

Michels, Joseph W., B.A., M.A., Ph.D.
Professor
Department of Anthropology
College of the Liberal Arts

Miller, K. L., B.S., M.S.
Health Physicist
Hershey Medical Center

Mueller, Werner J., Ing.Agr., Dr.Sc.Tech.
Professor
Department of Poultry Science
College of Agriculture

Naeye, Richard L., M.D.
Professor
Department of Pathology
Hershey Medical Center

Newnham, Robert E., B.S., M.S., Ph.D.
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Department of Material Sciences
College of Earth and Mineral Sciences

O'Brien, John H.
Reactor Supervisor, Nuclear Reactor
Department of Nuclear Engineering
College of Engineering

Parizek, Richard R., B.S., M.S., Ph.D.
Professor
Department of Geosciences
College of Earth and Mineral Industries

Penkala, John L., B.S.
Research Assistant
Department of Nuclear Engineering
College of Engineering

Pierce, William S., B.S., M.D.
Associate Professor
Department of Surgery
Hershey Medical Center

Pillay, Sivasankara, K. K., B.S., M.S., Ph.D.
Assistant Professor
Department of Nuclear Engineering
College of Engineering

Prasad Kadambi N., B.E., M.S., Ph.D.
Research Assistant
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College of Engineering

Pratt, William W., B.S., Ph.D.
Professor
Department of Physics
College of Science

Raupach, Dale C.
Reactor Supervisor, Nuclear Reactor
Department of Nuclear Engineering
College of Engineering

Robinson, Gordon E., B.S., M.S., Ph.D.
Associate Professor
Nuclear Engineering Department
College of Engineering

Rose, Arthur W., B.S., M.S., Ph.D.
Professor
Department of Geosciences
College of Earth and Mineral Sciences

Sanders, William T., B.S., M.A., Ph.D.
Professor
Department of Anthropology
College of the Liberal Arts

Schmotzer, Jack K., B.S., M.S.
Health Physics Assistant
Institute for Science and Engineering

Schultz, Mortimer A., B.S.
Professor
Department of Nuclear Engineering
College of Engineering

Stryker, John A., M.D.
Associate Professor of Radiotherapy
Hershey Medical Center

Totenbier, Robert E., B.S.
Research Assistant
Department of Nuclear Engineering
College of Engineering

Weidner, William A., M.D.
Department of Radiology
Hershey Medical Center

Witzig, Warren F., B.S., M.S., Ph.D., P.E.
Professor
Department of Nuclear Engineering
College of Engineering

Zarkower, Arian, D.V.M., M.S., Ph.D.
Associate Professor
Department of Veterinary Science
College of Agriculture

Graduate Students Utilizing the Facilities of the Penn State
Breazeale Nuclear Reactor (Including the Cobalt-60 Facility and
Radionuclear Applications Laboratory).

College of Agriculture

Hornick, S. B., Agronomy Department

Peters, James G., School of Forest Resources

Wilhelm, R. P., Horticulture Department (Undergraduate)

College of Earth and Mineral Sciences

Berkey, G. E., Material Science Department (Undergraduate)

Crock, J. G., Geosciences Department

Flynn, R. T., Geosciences Department

Schmiermund, R., Geosciences Department

Stapanek, J. G., Geosciences Department

College of Engineering

Arnold, R. H., Nuclear Engineering Department

Collins, H. E., Nuclear Engineering Department

Donlan, T. J., Nuclear Engineering Department

Fjeld, R. A., Nuclear Engineering Department

Houston, G. W., Nuclear Engineering Department

Jabs, R. H., Nuclear Engineering Department

Johannesmeyer, C. A., Nuclear Engineering Department

Klinetob, R. H., Nuclear Engineering Department

Kuis, R. L., Nuclear Engineering Department

Lee, B. W., Nuclear Engineering Department

Newcomb, P.C., Nuclear Engineering Department

Pandey, S., Nuclear Engineering Department

Ray, P. K., Nuclear Engineering Department

Rose, P. J., Nuclear Engineering Department

Runte, W. G., Nuclear Engineering Department

Schmotzer, J. K., Nuclear Engineering Department

Sider, R. G., Nuclear Engineering Department

Somma, S., Nuclear Engineering Department

Spears, W. R., Nuclear Engineering Department

Stover, E. K., Nuclear Engineering Department

Wolfe, F. A., Nuclear Engineering Department

College of the Liberal Arts

Brown, K. L., Anthropology Department

de Mendoza, L. H., Anthropology Department

Rice, P. M., Anthropology Department

College of Science

Herritt, J. A., Physics Department

Meyers, J. A., Physics Department

Pilione, L. J., Physics Department

Robinson, G. D., Biology Department

Slavinski, A. J., Biology Department

APPENDIX B
FORMAL GROUP TOURS

1974

July	9	Indiana University of Pennsylvania Art Students	10
	11	Upward Bound Students-P.S.U.	42
	17	Excellent Management Program	20
	26	Huntingdon Middle School	45
	30	Northeast Cooperative Extension Group	21
Aug.	1	Geological Science 303 Class-P.S.U.	25
	5	Law Enforcement & Correction Class	8
	8	Radio Park School 6th Grade	94
	19	University of Pittsburgh NucE 206 Class	15
	20	University of Pittsburgh NucE 206 Class	11
	27	Radionuclear Applications Seminar	11
Sept.	12	Nuclear Engineering 440 Class-P.S.U.	23
	25	Nuclear Engineering 401 Class-P.S.U.	10
	26	Seminar Group (startup & testing of Nuclear Power Plants)	5
	28	Pennsylvania State Police Laboratory System	6
	30	5th & 6th Grades from State College Area Schools	65
Oct.	1	Police Services - Penn State University	5
	3	Police Services - Penn State University	6
	4	Police Services - Penn State University	8
	8	Physics 100 Class - P.S.U.	18
	10	Physics 100 Class - P.S.U.	16
	15	Police Services - Penn State University	6
	22	Police Services - Penn State University	9
	24	Police Services - Penn State University	3
	25	Power Systems Engineers	35
	30	Environmental Resource Management Class-P.S.U.	17
	31	Bloomsburg State College Students	24

Nov.	1	Beattie Technical High School	15
	5	Pittsburgh Explorer Scouts	48
	5	Bucknell Nuclear Engineering Class	8
	6	Police Services - Penn State University	5
	7	Geological Science 303 Class - P.S.U.	21
	14	Penn Hills, Daniel Boone High Schools	10
	19	Wyomissing High School	75
	26	Lower Dauphin High School	17
	26	Altoona High School	7
	26	Police Services - Penn State University	8
Dec.	18	Doctors & Ambulance Drivers - Penn State University	18
	18	Nuclear Engineering 200 - P.S.U.	25
<u>1975</u>			
Jan.	10	Entomology Class - P.S.U.	16
	14	Family & Friends of Reactor Staff Member	10
	21	Physics 101 Class - P.S.U.	16
	22	Jershey Shore High School	10
	22	Environmental Health Class - P.S.U.	14
	22	Physics 101 Class - P.S.U.	18
	23	Physics 101 Class - P.S.U.	22
	28	Industrial Engineering Class - P.S.U.	5
	28	Altoona, Pa. Nuclear Engineering Tech. Group	27
	29	Carlisle High School Group	12
	29	Social Studies 430 Class - P.S.U.	24
	30	Life Science Class - P.S.U.	7
	31	Bio Physics 10 Class - P.S.U.	18
Feb.	11	Social Studies 430 Class - P.S.U.	18
	12	Social Science Class - P.S.U.	34
	13	Geological Science 303 Class - P.S.U.	51
	17	Dunmore High School	19

	18	Ligonier High School	21
	19	Chestnut Ridge High School	15
	20	Industrial Arts Education 160 Class - P.S.U.	27
	25	Graduate Review Committee	4
March	17	Fairmount Avenue 6th Grade	28
	18	Execter High School	10
	18	Juniata College Class	9
	20	Fairmount Avenue 6th Grade	24
	20	Penn Hills Senior High School	7
	21	Fairmount Avenue 6th Grade	27
	25	Higher Education Class - P.S.U.	5
	25	American Association of University Women	19
	25	Berwick Area Senior High School	21
	26	Pennsylvania Rural Electric Association	33
	31	Juniata High School	15
April	2	Higher Education 101 Class - P.S.U.	16
	3	Riverside Jr./Sr. High School	14
	7	Grier School	11
	8	Titusville High School	3
	8	Troy High School	10
	10	Brownsville High School	10
	10	St. Clair High School	18
	17	Plant Pathology 424 Class - P.S.U.	17
	17	Bellefonte High School	21
	19	Open House	287
	21	Cambria Heights High School	72
	24	Blue Ridge High School	20
	24	Penncrest High School	13
	24	Bishop O'Riley School	7
	25	South Allegheny High School	44
	25	Penn State ECO-Action	18

	29	West Perry High School	14
May	1	Harbor Creek High School	11
	2	Speech & Hearing Clinic - P.S.U.	6
	5	Lewistown High School	29
	6	Democratic Women of State College	17
	6	Parkland High School	14
	6	N. Schuylkill High School Class	6
	8	Greater Latrobe Senior High School Class	10
	8	West Jefferson High School	11
	9	Pennsylvania State Legislators & University Personnel	18
	12	Physics 100 Class - P.S.U.	13
	13	Physics 100 Class - P.S.U.	16
	13	Pottsville Area High School	10
	13	League of Women Voters	13
	14	Ceramic Science 441 Class - P.S.U.	17
	15	Hollidaysburg High School	13
	15	Nuclear Engineering 401 Class - P.S.U.	18
	15	Physics 100 Class - P.S.U.	20
	16	Nuclear Physics 406 Class - P.S.U.	10
	19	Metal 412 Class - P.S.U.	14
	20	Saucon Valley High School	6
	21	Nuclear Science Field Trip	19
	21	Conemaugh High School	32
	22	State College Area High School	138
	23	Lock Haven Elementary 6th Grade	35
June	3	Pine Glen 6th Grade	21
	5	Juniata Terrace 5th Grade	24
Total			2,700